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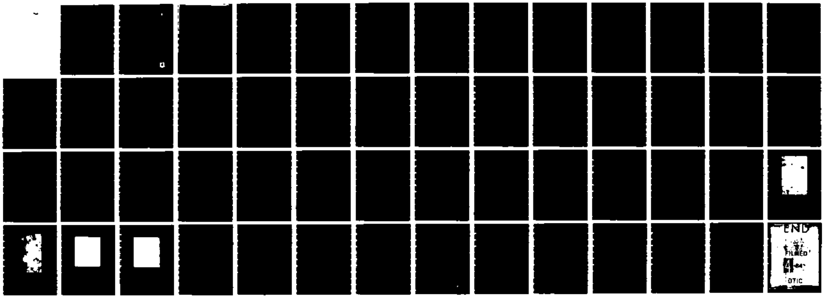

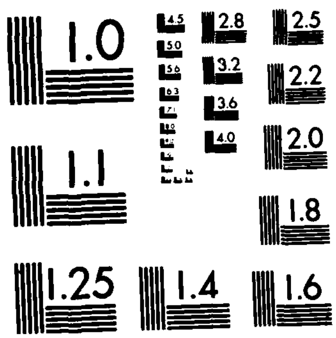

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A Catalog of Solar White-Light Flares (1859-1982), Including Their Statistical Properties and Associated Emissions

DONALD F. NEIDIG
EDWARD W. CLIVER

20 September 1983

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SPACE PHYSICS DIVISION PROJECT 2311
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AIR FORCE SYSTEMS COMMAND, USAF

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This catalog of 57 solar white-light flares reported between 1859 and 1982 includes Hα, soft X-ray, and radio emissions associated with the white-light flares. Statistical examination of the listed flares and the active regions in which they occurred yielded the following conclusions:

(1) The active regions that produce white-light flares tend to have the following characteristics: (a) magnetic class = Delta; (b) classification of the penumbra of the largest spot = K; and (c) sunspot group area > 500 millionths of the solar hemisphere.

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(2) Northern hemisphere white-light flare activity begins abruptly about 1 or 2 years before solar maximum, and declines slowly thereafter. Southern hemisphere white-light flare activity follows the same pattern, but begins approximately 1 year after solar maximum.

(3) White-light flares have a mean latitude of 13 ± 2° in the southern hemisphere but a mean latitude of 18 ± 1° in the northern hemisphere.

(4) White-light flares exhibit a north-south asymmetry with 70 % more events having been observed in the northern hemisphere as compared to the southern (the current solar cycle is a possible exception with southern hemisphere activity dominating) as of December 1982.

(5) There is no compelling evidence of preferred solar longitudes for white-light flare active regions. Southern hemisphere activity during the current cycle is a possible exception.

(6) The median value of Hα flare importance, soft X-ray burst class, and ≧ 8 GHz burst peak flux density for events associated with white-light flares are 2B, ~X3, and ~4000 sfu, respectively. The smallest (high confidence) values of these parameters observed in association with white-light flares are 1B, ~M5, and ~100 sfu.

(7) White-light flares exhibit a 60 percent association with Type II bursts, 70 percent with Type IV bursts, and 75 percent with proton events (Western hemisphere flares). We argue, however, that the strong association with proton events is simply an example of the "Big Flare Syndrome," rather than evidence for a close physical connection between white-light emission and the production of interplanetary protons.

Appendixes contain a brief discussion of white-light flare morphology, spectra, and energetics, and supplemental lists of white-light flares not included in the main catalog.

Preface

We wish to thank J. Buchau and D. Hardy of AFGL, Space Physics Division, for their assistance in translating German and French literature on white-light flares.

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A Catalog of Solar White-Light Flares (1859-1982), Including Their Statistical Properties and Associated Emissions

1. DEFINITION

Historically, a white-light flare (WLF) has been defined to be any solar flare that becomes visible in integrated light against the background disk of the sun. In this report, we also designate as WLFs those events in which emission is observed in the bandpass of a filter that isolates a portion of the spectrum, provided that the filter excludes the strong chromospheric lines. For this latter type of observation, we do not restrict the wavelength range to the visible (4000-7000 Å), but include flares that only show detectable emission at wavelengths below 4000 Å (including emission near the head of the Balmer continuum).

2. BACKGROUND

Ever since Carrington and Hodgson's discovery in 1859 of the first solar white-light flare—in fact, the first flare directly observed at any wavelength—white-light flares have retained a status as one of the premier types of solar activity. Their importance has long been recognized both in terms of the geophysical disturbances they produce and in their relevance to the energy release processes that occur in

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highly energetic flares. The 1859 flare was followed by a large geomagnetic storm[1] and it is probably fair to claim that the inferred association between these two phenomena contributed heavily to the foundation of modern solar-terrestrial research. More recently (within the last two decades) it has been realized that WLFs may represent an aspect of the flare phenomenon that cannot be easily reconciled within the context of existing flare atmospheric and energy transport models.

Owing to their comparative rarity, WLFs have not, as a class of events, been comprehensively studied. Among those aspects in need of further observational descriptions are (1) morphology (a description of the various WLF forms in terms of magnetic field geometry and dynamics), (2) timing (with respect to other flare emissions, both thermal and nonthermal, originating over a wide range of temperatures and heights in the solar atmosphere), and (3) optical and ultraviolet spectra (leading to a radiative transfer solution and a WLF model atmosphere).

Historically, observations of WLFs have been hampered by poor time resolution, lack of quantitative intensity measurements, poor (most often non-existent) spectral coverage, and lack of simultaneous measurements in different regions of the electromagnetic spectrum (particularly hard X-rays and EUV). In response to these deficiencies, a patrol telescope, specifically designed to provide optical images, polarization, and broad-band spectral data, was put into operation at Sacramento Peak Observatory in June 1980.[2] Called the Multiple-Band Polarimeter (MBP), the telescope consists of a 4.5-inch objective lens followed by a Wollaston prism and filter system that allows a programmable selection of five wavelengths/bandpasses at 3610/22, 4275/40, 4957/48, 5645/50 and 6203/48 Å. Simultaneous with this program, a parallel effort was initiated to obtain spectrographic data with the 40-cm coronagraph and Universal Spectrograph (USG) at Sacramento Peak. During 2-1/2 years of operation (June 1980 - December 1982), at least 12 WLFs have been observed, 6 of which were recorded by both the Multiple-Band Polarimeter and the Universal Spectrograph.

Preliminary studies of these flares led naturally to a search for information on previously known WLFs. This work evolved into the compilation of a catalog of WLFs that included data on active region types, heliographic coordinates, and various associated flare emissions. This report is intended to be that catalog, giving background information for future studies of WLFs. In Section 3 we present the catalog and discuss the criteria for inclusion of an event in our list of WLFs. In Section 4 we discuss various statistical characteristics of WLFs and the active

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1. Carrington, R.C. (1859) Description of a singular appearance seen in the sun on September 1, 1859, Monthly Notices Roy. Astron. Soc. **20**:13.
2. Neidig, D.F., and Beckers, J.M. (1983) Observing white-light flares, Sky & Telescope **65**:226.

regions in which they occur. These include the magnetic field and sunspot classifications of WLF active regions, the epoch and heliographic location of WLFs, and the associations of white-light emission with flare Hα, radio, X-ray, and particle emissions. In Section 5 we summarize our main conclusions.

This report also contains three appendixes. In Appendix A we briefly discuss the interesting topics of WLF morphology, spectra, and energetics. This is done to summarize current knowledge and to suggest directions for future studies. Appendixes B and C contain supplemental lists of possible WLFs that have not been included in our main catalog. These excluded events will be discussed further in Section 3.

3. A CATALOG OF WHITE-LIGHT FLARES, 1859-1982

Svestka distinguishes three types of continuous emission in the optical region of flare spectra:[3]

(1) Weak continuum in flares above the limb.
(2) Narrow emission threads in the spectra of disk flares.
(3) Short-lived continuous emission from disk flares.*

For the purpose of this study we have considered only those events satisfying the third definition, thus eliminating off-limb events, [that is, low background intensity events such as those on 09 June 1959 (Jefferies and Orrall[4]) and 07 September 1957 (Kiepenheuer and Kuenzer[5])] and flares with small grains of continuous emission visible in the flare spectrum as narrow "threads" such as those on 07 December 1938 (Richardson and Minkowski[6]) and 27 August 1956 (Severny[7]). In this latter type of event the grains producing the thread-like continuous emission often do not coincide in position with the flare elements that produce the line emission. This phenomenon is relatively common and is not restricted to large flares; it may even occur in active regions in the absence of a flare.

To obtain records of WLFs observed before 1970 we relied on the lists of events published by Du Martheray,[8] Fritzova et al,[9] Becker,[10] Korchak,[11] Svestka,[12] McIntosh and Donnelly,[13] and Slonim and Korobova.[14] For WLFs occurring since

*We do not distinguish between WLFs observed near the center of the solar disk and those observed near, but not off, the limb. Svestka[3] (p. 92) notes that the larger areas and longer durations of certain WLFs observed near the limb (for example, Event Nos. 18 and 23 in Table 1) suggest that some additional emission process, rendered visible by the improved contrast near the limb, might be involved.

(Due to the large number of references cited above, they will not be listed here. See References, page 33.)

1970, over half of which were observed at Sacramento Peak, we compiled the list ourselves. To the best of our knowledge the final list of events is comprehensive, although we have recently received information from Zirin[15] that several additional WLF candidates occurred in 1979, 1980, and 1981; these latter events are not yet recorded in the literature and we have no details on them. We did not include suspect events such as those of 11 August 1954 reported by Miller[16] and 30 August 1957 reported by McNarry[17] (see Appendix B). Because of the often incomplete nature of the observations, our decisions to include or exclude events from the catalog involved subjective judgments over which ther[illegible]y be legitimate disagreement. With this caveat, our final list of events is gi[illegible] in Table 1.

For completeness, two additional lists of possibl[illegible].Fs are given in Appendixes B and C. The first of these includes all event[illegible]t have been reported in the literature as WLFs but do not meet our definition of [illegible] or for which the observation is questionable. The second of these lists c[illegible]prises those events that have been reported as having continuous emission in the Quarterly Bulletin of Solar Activity (QBSA) or Solar Geophysical Data (SGD), but that have not been specifically addressed in the literature. In our opinion, the majority of the events in Appendix C that were observed before 1970 are legitimate WLFs. However, since we had no additional information or description of these events, we chose not to include them in the main catalog. During April and May 1972, 17 WLFs were reported in Solar Geophysical Data. All but one of these was associated with an Hα subflare (with seven classified as faint subflares). For each of these events continuous emission was reported only by a single Air Weather Service observatory (Teheran, Athens, Ramey, or Palehua). The 17 flares originated in 10 different active regions with magnetic and sunspot classifications ranging from very simple (αP, AXX for McMath 11794 on 01 April 1972) to complex (δ, EKO for McMath 11883 on 18 May 1972). Even if the reports of continuous emission in these flares are legitimate, it seems doubtful that these events are of the same nature as those in Table 1.

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15. Zirin, H. (1983) private communication.
16. Miller, W.A. (1955) Intensity variation in sunspots, Nature **175**:557.
17. McNarry, L. R. (1960) The observation of a solar event in white light from Resolute, N.W.T. on August 30, 1957, J. Roy. Astron. Soc. Canada **54**:273.

Note: References 18 through 59 are noted in Table 1 and References 60 through 72 are noted in the "Explanation to Table 1", and are too numerous to list. See References, page 33 for listing.)

Table 1. A Catalog of White-Light Flares, 1859-1982

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)		(17)		(18)		(19)	(20)	(21)	(22)
				Hα				X-Ray	White Light				Microwaves			Sweep Frequency Radio						Protons			
Event No.	Year	Month	Day	Max U.T.	Flare Class	LAT	LONG	1-8A Class	Start	Max	Dur	λ	t_{max}	S_p (≥8 GHz)	UT	III		II		IV		Log >10MeV	GLE	Ref	Notes
(1)	1859	Sep	01	N/A	3+	N20	W12	N/A	1118±0.25	---	5(+2,-0)	WL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[illegible]	
(2)	1872	Nov	13	N/A	?	?	?	N/A	1045	---	≥15	WL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[illegible]	
(3)	1891	Jun	17	N/A	3	N21	W80	N/A	1016	---	≥4	WL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[illegible]	
(4)	1892	Jul	15	N/A	?	~S30	~W15	N/A	1705	---	≥20	WL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[illegible]	1
(5)	1921	Feb	21	N/A	3+	S07	W42	N/A	1225	1229	7-8	WL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[illegible]	
(6)	1921	Sep	21	N/A	?	N10	W32	N/A	1245	---	1-2	?	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[illegible]	
(7)	1926	Oct	13	N/A	?	?	?	N/A	1413	---	---	?	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[illegible]	
(8)	1928	Sep	22	N/A	?	?	?	N/A	1405	---	1	WL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[illegible]	2
(9)	1937	Jul	26	N/A	3	N32	E31	N/A	---	~1000?	---	WL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[illegible]	
(10)	1938	Mar	31	~1050	2+	S20	E82	N/A	1019	1034-40	≥40	3220	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	[illegible]	
(11)	1946	Mar	05	?	3	N28	E10	N/A	1123.5	1125.4	3.8	WL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	---	[illegible]	
(12)	1946	Jul	25	1627	3+	N22	E15	N/A	<1627	---	---	6200	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1100	[illegible]	
(13)	1948	Dec	11	?	3	S09	E48	N/A	≤0818	0820	≥12	WL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	---	31	
(14)	1949	Nov	19	1032	3+	S02	W70	N/A	<1036	---	---	6500	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2000	[illegible]	
(15)	1951	May	18	?	3	N18	W35	N/A	---	~1300?	---	WL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	---	[illegible]	3
(16)	1956	Feb	23	0342	3	N23	W74	N/A	≤0345	≤0345	≥5	WL	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	PCA(3)	4554	[illegible]	4
(17)	1957	Sep	03	1428	3	N24	W30	N/A	1424	---	~6	WL	?	(>515)	1424	1424	1425	---	---	---	---	PCA(≥1?)	---	[illegible]	5
(18)	1958	Mar	23	1005	3+	S14	E74	N/A	1001	1004	7-8	WL	<9.4?	--?	1002	N/A	N/A	N/A	N/A	N/A	N/A	PCA(2)	---	[illegible]	6,7
(19)	1958	Mar	30	0845	2	N34	E63	N/A	0844	--	2	WL	<9.4?	--?	0844	N/A	N/A	N/A	N/A	N/A	N/A	---	---	[illegible]	7,8
(20)	1958	Jun	19	1445	1+	N15	W26	N/A	<1444	---	---	3832	<9.4?	--?	1439	---	---	---	---	---	---	---	---	[illegible]	7,9
(21)	1958	Jul	29	0304	3	S13	W44	N/A	≤0307	---	>2	(4100)	>9.5	5900	0304	---	---	0304	0319	0321	>0500	PCA(2)	---	[illegible]	10

Table 1. A Catalog of White-Light Flares, 1859-1982 (Contd)

Event No.	(1) Year	(2) Month	(3) Day	(4) Hα Max U.T.	(5) Hα Flare Class	(6) Hα LAT	(7) Hα LONG	(8) X-Ray 1-8A Class	(9) White Light Start	(10) White Light Max	(11) White Light Dur	(12) White Light λ	(13) Microwaves f_{max}	(14) Microwaves Sp (≥8 GHz)	(15) Microwaves UT	(16) Sweep Frequency Radio III		(17) Sweep Frequency Radio II		(18) Sweep Frequency Radio IV		(19) Protons Log >10MeV	(20) Protons GLE	(21) Ref	(22) Notes
(22)	1959	Sep	03	0422	2+	N26	W86	N/A	<0424	---	---	(4100)	3.0	981	0421	0422	0423	0424	0438	---	---	PCA?	---	11	11
(23)	1960	Sep	03	0107	2+	N18	E87	N/A	≤0105	0107.5±.5	≥15	WL	>9.5	10850	0106	0103	0105	?	?	0038	>0054	2?	4	37	12
(24)	1960	Nov	15	0221	3+	N26	W32	N/A	~0221 ~0223.5	---	≤2	WL	>9.4	≥20000	0222	---	---	0221	0248	0221	>0608	4	88	38	13
(25)	1963	Sep	26	0715	3+	N16	W78	N/A	<0717	---	---	(4100)	>9.5	3626	0715	N/A	N/A	N/A	N/A	N/A	N/A	1?	---	11	
(26)	1967	May	21	1926	2N	N24	E39	N/A	1922±4	1926±2	≥4	5800	8.8	1966	1925	1922	1926	1923	1945	1923	2100	-2	---	13	14
(27)	1967	May	23	1844	3B	N27	E24	N/A	1837±0.25	1840	~9	5800	>8.8	8100	1840	1835	1838	1838	1905	1839	2320	>1	---	39,40	
(28)	1968	Jul	06	0956	1N	N14	E90	N/A	0945	---	≥9	WL	19.0	180000	0948	0946 0955	0951D 0957D	---	---	0945	1004d	0	---	41	
(29)	1969	Feb	25	0914	2B	N13	W37	N/A	---	0912?	---	WL	~10	5562	0913	0901 0905	0902 0906	---	---	0904	1130	1	16	13	
(30)	1969	Mar	12	1744	2B	N12	W80	(>X10)	1741±0.5	1742±1	~13	5800,s	15.4	5000	1741	1745	1746	1741	1759	1741	1748	0	---	13,42	
(31)	1969	Sep	27	0357 0412	3N 3B	N06	W00	(~X2?)	<0356	---	---	(4100)	~3	10	0355	0355 0359	0356 0401	0402	0420	0359	>0808	-1	---	11	
(32)	1970	Mar	26	2011	1B	N06	E66	X2	?	?	?	s	5.0	495	2008	2005	2010	2009	2030	2010	2035	?(0)		43	
(33)	1970	Nov	17	0744	2B	N17	W35	(>X12)	<0750	---	---	(4100)	9.1	600?	0749	---	---	---	---	---	---	-1	---	14	15
(34)	1972	Aug	02	1844	1B	N14	E26	M8	1839.5	1839.75	~1	3835	5.0 >37.0	(900) 885	1840	---	---	---	---	1839	1843d	?(0)	---	44	16
(35)	1972	Aug	02	2058	2B	N14	E28	X3.6	~2001 ~2030 ~2140	--- --- ---	≤5 ~35 ≤5?	3835 3835 3835	8.8 8.8 ~5	156 ~6600 8101	2002 2046 2145	1959 2021	2003 2100	---	---	2030	2250	?(0)	---	44	16
(36)	1972	Aug	07	1534	3B	N14	W37	(>X10)	<1520 1524	1522.5±1 ---	~4 ≤16	5000 5000,s	18.0	~23000	1522	1513	1521	1519	1614	1517	1540	>2	8	45,46,47	17
(37)	1974	Jul	04	1357	2B	S16	W08	(<X8)	1354	---	≥4	WL	>71.0	8436	1354	1353	1356	1359	1407	1353	1446	1	---	48,49	

Table 1. A Catalog of White-Light Flares, 1859-1982 (Contd)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)		(17)		(18)		(19)	(20)	(21)	(22)
				Hα				X-Ray	White Light				Microwaves			Sweep Frequency Radio						Protons			
Event No.	Year	Month	Day	Max U.T.	Flare Class	LAT	LONG	1-8A Class	Start	Max	Dur	λ	f_{max}	Sp (28 GHz)	UT	III		II		IV		Log >10MeV	GLE	Ref	Notes
(38)	1974	Sep	10	(2146)	2B	N10	E61	X2	<2134	2139	>10±2	s	~9	9350	2140	2135	2207	2135	2210	2134	2220	1	---	50	18
(39)	1978	Jul	09	1822	2B	N19	E68	X3.4	1819.5	1828	9	3835	>15.4	2020	1828	1809	1827	---	---	1833	1925	---	---	51	
(40)	1978	Jul	10	1734	2B	N17	E54	M7.9	1729.6	≤1730	~0.2	3835	>15.4	310	1730	1730	1740	1740	1747	1736	1739	?(A)	---	51	
(41)	1978	Jul	11	1057	2B	N18	E45	X15.0	≤1053	≤1053.5	>4	WL	~15?	>10000	1053	1052	1055	1051	1059	1051	>1407	?(A)	---	52,53	
(42)	1980	Jun	03	2132	1B	S14	E67	M7.2	---	2136	---	s	~12?	480	2131	2128	2132	2133	2153	2132 2146	2152d 2248	---	---	54	
(43)	1980	Jun	04	2301	1B	S13	W69	X2.2	---	2300	---	s	~9	470	2301	---	---	2303?	2306?	---	---	---	---	54,59	19
(44)	1980	Jul	01	1629	1B	S12	W38	X2.5	1627	≤1629	≤5	MBP	11.8 >35.0	1706 2700	1627	1627	1635	1628	1651	1628	1641	---	---	55	
(45)	1981	Jan	27	1547	1B	S13	E63	M4.6	~1544.5	1545	~2	MBP	~8	250	1545	---	---	---	---	---	---	---	---	51	20
(46)	1981	Feb	26	1953	2B	S15	E50	X4.0	<1950	---	>2	WL	8.8	5200	1950	1952	1956	1951	2012	2009 2038	2025 2048	---	---	56	
(47)	1981	Apr	24	1356	2B	N18	W50	X5.9	1347	1357	21	MBP,s	>15	≥10000	1400	1353	1444	1355	1429	1356	1505	2	---	57	
(48)	1981	May	13	0353 0425	2B	N11	E57	X1.5	≤0403	0412	>35	s	~6?	4362	0419	0350	0536	0400?	0406?	---	---	~0?	---	58	
(49)	1981	Jul	26	1354	2B	S15	E27	X3.5	---	~1353	≥6	s	19.6	1020	1354	1350	1353	---	---	1349	1354d	?(-2)	---	SP	
(50)	1982	Jun	04	1330	2B	S10	E55	X5.9	~1326	1331	10	MBP,s	>35.0	5267	1328	1333	1342	---	---	1335	1358	?(0)	---	SP	
(51)	1982	Jun	04	1423	2B	S10	E54	X2.4	1420	1421.5±.5	8.5	MBP,s	~10	~1400	1421	1420	1428	---	---	---	---	?(0)	---	SP	
(52)	1982	Jun	05	1529	1B	S12	E42	M7.1	1528	~1529	8	MBP	>15.4	120	1530?	1531	1532	---	---	---	---	?(1)	---	SP	
(53)	1982	Jun	06	1651	2/3B	S10	E25	X12.0	~1632	1634	5	MBP,s	~15	≥4000	1634	1632	1640d	1634	1716	1642	1727	?(1)	---	SP	
(54)	1982	Jun	25	2141	1B	N17	W61	M7.5	---	~2135	---	s	~9	594	2134	2133	2136	---	---	2135	2139	?(-1)	---	SP	
(55)	1982	Jun	26	1915	2B	N16	W73	X2.1	1911	1913	7	MBP,s	~10	~800	1912	1911	1919	---	---	---	---	?(-1)	---	SP	
(56)	1982	Dec	15	0201	2B	S09	E24	X12.9	---	---	---	---	>15.4	17000	0202	0158	0201	0200	0227	0201	0220	0?			
(57)	1982	Dec	17	1857	3B	S07	W20	X10.1	1853	1856	7	MBP,s	>15.4	4000	1857	---	---	1901	1907	---	---	1		SP	

Explanation of Table 1

Column	
1, 2, 3	Year, month, and day of event.
4, 5, 6, 7	Time of Hα flare maximum, Hα flare classification, latitude and longitude of flare. Data sources are the Quarterly Bulletin of Solar Activity (QBSA) and Solar Geophysical Data (SGD) in addition to the listed reference. For Event Nos. 1, 3, 5, and 8 the flare class is after Svestka.[12] For Event No. 3, the flare coordinates are after Becker.[10] Du Martheray[8] locates Event Nos. 7 and 8 in "Groupe 170" and "Groupe 202," respectively (these are presumably local observatory designations that we were unable to convert to standard coordinates). For Event Nos. 45-57, the Hα class, timing and position data are averaged values from SGD prompt reports, Boulder preliminary reports, or pre-publication lists courtesy of World Data Center A. N/A = No Observations; ? = Data Not Reported.
8	Soft-X-ray class. Before 1973 these data are from the SOLRAD satellites; after 1973, from SMS/GOES. Data sources are SGD, Donnelly,[60] and Donnelly and Bouwer.[61] Values in parentheses are uncertain due to data gaps or saturation. The peak intensities of the soft X-ray events observed by SOLRAD have been multiplied by a factor of two to make them compatible with the SMS/GOES observations of Kreplin et al.[62] N/A = No Observations.
9, 10, 11	Start time, time of maximum, and duration of the continuum emission. All times are UT except Event No. 2 for which the source does not indicate whether the reported times are local or universal, Event No. 6 (T.M.C. Belge), and Event Nos. 7 and 8 (T.M. Geneve). Dashes indicate data not reported while question marks indicate uncertainties in reported values. Duration is in minutes.
12	Wavelength of the white-light observations. WL = integrated light; MBP Multiple Band Polarimeter (see Section 2); s = spectrogram. Numbers indicate wavelength (Å) of broad-band filtergram; numbers in parentheses indicate effective wavelength (as for certain photographic emulsions).
13, 14, 15	Frequency (GHz) of microwave spectral maximum, largest peak flux density (10^{-22} W m^{-2} Hz^{-1}) at any frequency $\geqq$ 8 GHz, and time of the reported cm-λ burst peak (All three parameters

13, 14, 15 (Contd)	refer to the burst peak coincident with the WLF). Data sources are QBSA and SGD (Boulder preliminary reports for Event Nos. 52, 56 and 57). The "≧" sign preceding the spectral maximum indicates that the peak burst flux density occurred at the highest frequency at which observations were made. The peak flux density values listed represent averages when more than one station was reporting in a given frequency range, as was generally the case near 9 GHz. Peak flux density values in marked disagreement with the consensus of values at the same or nearby frequencies were ignored. N/A = No Observations; dashes indicate that a station was assumed to be on patrol, but did not report an event.
16, 17, 18	Start and end times of metric Type III, II, and IV bursts, respectively. Data sources are QBSA and SGD. The possible Type II bursts for Event Nos. 43 and 48 are from R. Stewart (private communication). If only decimetric (d) or decametric (D) bursts were reported these are listed with the appropriate frequency designator (d or D). A dash indicates that a station was on patrol, but did not report an event; N/A = No Observations.
19	The logarithm of the prompt > 10 MeV proton flux $(cm^2\ s\ ster)^{-1}$ according to the proton event classification system of Smart and Shea.[63] Data sources are Svestka and and Simon,[64] SGD,[19] Dodson et al,[65,66] and IMP data for recent events as kindly supplied by R. E. McGuire. (Listed values for the most recent (1982) events may change slightly as more complete data become available.) Delayed flux maxima associated with geomagnetic storm sudden commencements were disregarded. PCA = polar cap absorption event (that is, satellite observations not available). The number in parentheses following PCA is the logarithm of the > 10 MeV flux equivalent to the peak riometer absorption (after Smart and Shea[63]). "?(A)" indicates that a particle event following the listed flare may have, in fact, been due to another candidate parent flare; thus, "A" implies ambiguity.

19 (Contd)	A question mark followed by a number in parentheses indicates that the flare occurred when the > 10 MeV background was enhanced (> 0.01 particles cm^{-2} s^{-1} $ster^{-1}$) due to an earlier event, where the number is the logarithm of the background flux (masking level). For these cases, no convincing increase of the > 10 MeV proton flux was observed following the listed flare. Question marks following listed values indicate uncertainty. N/A = No Observations; dashes indicate that no event was reported.
20	Percentage increase in the cosmic ray counting rate due to a Ground Level Event (GLE). Data source is Cliver et al.[67] After 1978, a dash indicating the absence of a GLE is to be treated with caution, since the reporting of GLE events is often delayed. Otherwise, dashes indicate that no event was reported. N/A = No Observations.
21	References. Numbers refer to entries in list of References; SP = Sacramento Peak Observatory.
22	Explanatory notes.

Explanatory Notes to Table 1

(1) Becker[10] gives the flare coordinates as N10W90, but the drawings in Rudaux[23] clearly depict a disk event. We derive approximate coordinates from descriptions by Hale[68,69] who gives dates of limb passages and general location on the disk; Hale[70] further gives the latitude (S32) of the active region when it first appeared on the rotation previous to that of the flare.

(2) D'Azambuja,[71] citing Du Martheray,[26] gives 21 September as the date of the flare. However, in Du Martheray[8] the date is listed as 22 September. We were unable to obtain a copy of Du Martheray's 1946 report.

(3) In his brief report on this event, Porret[33] comments, "À 15 heures (T.U.) elle était encore observable, quoique de moindre intensité." No Hα activity is reported near 1500 UT, while reported maxima for the earlier (1300 UT) event are grouped closer to 1100 UT.

(4) The Nagoya 3750 MHz radiometer was the highest frequency instrument on patrol during the time of this flare.

(5) In Becker's[10] table of WLFs he lists 1424-1443 UT as the time of the continuum emission. This does not agree with the text of the paper, which supports the times listed here. The S_p ($\geqq$ 8 GHz) value listed is actually the burst mean flux density. Only mean flux density values were reported at the higher frequencies for this event and thus the spectral maximum could not be determined. Continuum sweep frequency emission was reported from 1455 - 1456 UT; Svestka and Simon[64] list this as Type V (?).

(6) Waldmeier[35] reports that at Locarno, the flare was visible in integrated light from 1005 - 1055 UT. Becker's[10] shorter duration is listed (instead of that reported by Slonim and Korobova,[14] p. 400). *Intense* ($\gtrsim$ *1000 sfu*) bursts were reported at 3 GHz.

(7) This flare occurred during the nominal patrol hours for Gorky and Heinrich Hertz, both of which have patrols at ~9 GHz, but neither station reported an event at this time.

(8) Nederhorst reported the only cm-λ burst at this time (S_p(2980 MHz) = 385 sfu at 0844 - 0845 UT).

Explanatory Notes to Table 1 (Contd)

(9) Heinrich Hertz and Ottawa report moderate intensity (S_p(1.5 GHz) = 109 sfu; S_m(2.8 GHz) = 48 sfu) bursts at 1439 UT. A weak Type I metric event was reported by Harvard from 1307 - 1954 UT.

(10) Type III bursts were reported from 0319-0321 and from 0334-0336 UT (Type V also).

(11) The listed flare is a good candidate to have produced the factor of two increase in the >75 MeV proton flux observed by Explorer 6 beginning at 0445 UT with maximum at 0520 UT (Svestka and Simon[64]).

(12) Harvard sweep frequency observations ended at 0110 UT; Sydney did not observe on this day.

(13) The peak 9.4 GHz emission near the time of the WLF is from Kodama et al.[72] No Type III events are listed for the entire day in QBSA.

(14) The proton flux estimate is based on observations at Pioneer 7 which was more favorably located (1.06 AU, ES angle = -36.5°) than earth-orbiting satellites for viewing this event. At lower energies, the event was observed by VELA 4.

(15) Gorky reports several peaks at 9.1 GHz (~0735 UT, 270(?) sfu; 0737.2 UT, 1460 sfu; 0744.8 UT, 1165 sfu; and 0748.9 UT, 600 sfu). The last peak, occurring closest to the time of the WL observation, is listed. Weissenau reports Type Is, cont (metric, intensity 2) from 0705-1506 UT.

(16) Svestka,[3] p. 86 comments, "The passband... contained the H9 line of the Balmer series of hydrogen; thus, it is not clear whether Zirin and Tanaka recorded white light flashes or tiny impulsive H9 kernels." See, however, Zirin.[51] For the event at ~1840 UT, the 900 sfu value in column 14 was recorded at 5 GHz.

(17) Machado and Rust[46] obtained a spectrogram of a fainter WLF "wave" at 1528:50 UT, showing continuum from the instrumental limit at 3580 Å to ~4300 Å. However, spectral data were not obtained for the brightest four knots of the flare.

(18) The estimated time of Hα maximum is the average of the times reported by Palehua (2137 UT) and Boulder (2155 UT).

(19) Culgoora reports DCIM (fast drift decimetric) emission from 2259-2302 UT.

Explanatory Notes to Table 1 (Contd)

(20) An intensity 2, Type I metric event was reported by Harvard from 1416-2345 UT (their entire observing day). Also, several Type III events, although none at this time, were reported throughout the day.

4. ANALYSIS

4.1 Characteristics of Active Regions That Produce WLFs

WLFs, like powerful flares in general, originate in large, complex active regions. Table 2 lists all known WLFs since 1972, along with their magnetic classification, spot group classification, and group area, according to Solar Geophysical Data* (detailed descriptions of these classification schemes are published annually in the Solar Geophysical Data, Descriptive Text).

In Table 2 it can be seen that nearly all (20/24) of the recent WLFs occurred in active regions containing a "delta" magnetic configuration. This configuration is defined to exist whenever spots of opposite polarity are located within 2 heliographic degrees of one another and within the same penumbra. Among the magnetic classifications encountered for solar active regions in general, the delta configurations are rare in comparison to the more common unipolar, simple bipolar, or even the mixed polarity (gamma type) regions.

The classification of active regions, based on sunspot morphology, is given in Solar Geophysical Data by a three-letter code. The first letter defines the spatial extent and stage of development of the sunspot group, the second describes the size and shape of the largest spot in the group, while the third describes the distribution of individual spots within the active region. WLF-producing regions are, with regard to the first letter classification, characterized by well developed sunspot groups with penumbras on spots of both polarities (classes D, E, or F); the distinction between classes D, E, and F is set by the spatial extent of the region in heliographic longitude, namely, less than 10°, 10° - 15°, and greater than 15°, respectively.**

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*These data have been published in Solar Geophysical Data beginning in 1969, but only since December 1971 has the McIntosh sunspot group classification been used.

**The only WLF active region on our list that did not have D, E, or F description was Hale region 17491 on 26 February 1981. The modified Zurich sunspot class for this event was listed "E" on the 25th, "C" on the 26th, and "D" on the 27th.

Table 2. White-Light Flares Since 1972, and Their Associated Active Region Characteristics

Event No.	Date	UT	Mag. Class[a, d]	Spot Class[b, d]	Area[c, d]
34.	1972 Aug 2	1844	D	EKC	1050
35.	1972 Aug 2	2058	D	EKC	1050
36.	1972 Aug 7	1534	D	EKC	910
37.	1974 Jul 4	1357	D	FKC	1020
38.	1974 Sep 10	2146	D	DKC	750
39.	1978 Jul 9	1822	D	DKO	760
40.	1978 Jul 10	1734	D	EKC	1080
41.	1978 Jul 11	1057	D	EKC	1330
42.	1980 Jun 3	2132	D	DKO*	310*
43.	1980 Jun 4	2301	D	EKI	990
44.	1980 Jul 1	1629	B	EKI*	400*
45.	1981 Jan 27	1547	BG*	DKI*	520*
46.	1981 Feb 26	1953	GD*	CKI	520
47.	1981 Apr 24	1356	D	DKC	1170
48.	1981 May 13	0353	D	FKC	1510
49.	1981 Jul 26	1354	B	FKI	2140
50.	1982 Jun 4	1330	D	EKC	930
51.	1982 Jun 4	1423	D	EKC	930
52.	1982 Jun 5	1529	D	FKC	1160
53.	1982 Jun 6	1634	D	EKI	1180
54.	1982 Jun 25	2141	D	EKI	940
55.	1982 Jun 26	1917	B	EKI	560
56.	1982 Dec 15	0159	BGD*	DKI*	270*
57.	1982 Dec 17	1858	BGD*	DKI*	500*

[a]Magnetic Class: B (Bipolar), G (Gamma), and D (Delta); (see text and Solar Geophysical Data, Descriptive Text).

[b]Spot Group Class (see text and Solar Geophysical Data, Descriptive Text).

[c]Sunspot Group Area, in millionths of the solar hemisphere.

[d]Entries followed by asterisks have been taken from the Boulder preliminary reports.

All of the WLFs in Table 2 occurred in active regions containing a large, asymmetric penumbra, as designated by second-letter class K. Class K requires that the largest sunspot in the group have an area exceeding 240 millionths of the solar hemisphere (diameter greater than 2.5 heliographic degrees). Nearly all

(21/24) of the listed regions had sunspot group areas $\gtrsim$ 500 millionths and the majority (15/24) had areas $\gtrsim$ 1000 millionths.* In many cases the major portion of this total area was contained in one large penumbral complex (see Appendix A) As an aside it may be noted, according to Solar Geophysical Data, Descriptive Text, that when the sunspot group area exceeds approximately 950 millionths it is almost certain that both magnetic polarities will be present within a common penumbra and that the first-letter classification will become D, E, or F.

The third-letter classifications show that WLFs favor regions in which the zone between the leading and following ends of the sunspot group are populated by spots as well. The class of highest population of intermediate spots is designated C; this class is followed, in order of decreasing intermediate population, by classes I and O. Most (22/24) of the WLF active regions bear classifications C and I.

In generalizing the characteristics of WLF-producing regions we may safely claim that they tend to be large in sunspot group area, with complex magnetic structures in which opposite magnetic poles are located in close proximity to one another. The latter condition implies a steep magnetic field gradient across the line of polarity reversal—a well known characteristic of active regions that produce large and many flares. In arriving at these conclusions it is necessary to point out that the use of instruments such as the MBP, which view individual active regions rather than the full sun, introduces the possibility of a selection effect, due to the tendency to focus on regions with large sunspots and complex magnetic fields. We note, however, that the picture of WLF active regions we have drawn is not inconsistent with that inferred from WLF observations made prior to solar cycle 21.

4.2 Statistics Involving Epoch and Location

The data in Table 1 can be used to establish the occurrence of each WLF relative to cycle epoch, that is, the year of the flare's occurrence in relation to the year in which the maximum of the particular solar cycle is reached (Figure 1). We have used the year of largest sunspot (Wolf) number as defining solar maximum. In Figure 1 we have denoted by an asterisk those WLFs occurring in active regions that had previously produced one or more WLFs during the transit of the region across the solar disk. The events without asterisks therefore represent the epoch

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*In contradistinction to the WLFs listed in Table 2, four of the five events observed from 1969-1971 (Event Nos. 29-32) had sunspot group areas < 500 millionths. Group area data are not available on a daily basis in Solar Geophysical Data prior to 1969. Limited data for pre-1969 events, however, indicate a distribution of spot group areas similar to the distribution for the events in Table 2; the Greenwich Photo-Heliographic Results[73] were particularly useful in this regard.

73. Greenwich Photo-Heliographic Results, Her Majesty's Stationery Office, London.

distribution of WLF-producing active regions. Three WLF regions (corresponding to Event Nos. 45, 47, and 54) discovered at Sacramento Peak Observatory were not independently observed as WLF-producers by any other observatory. Noting this, and the fact that their discovery was a direct result of the intensive patrol program that began in June 1980, after the maximum of cycle 21, we conclude that the inclusion of these regions in Figure 1 would bias the distributions toward higher epoch values. By excluding the latter three regions as well as the asterisked events we obtain the unbiased distribution of WLF regions (shaded areas in Figure 1); the mean epoch of this distribution is $+1.24 \pm 0.30$ yr.

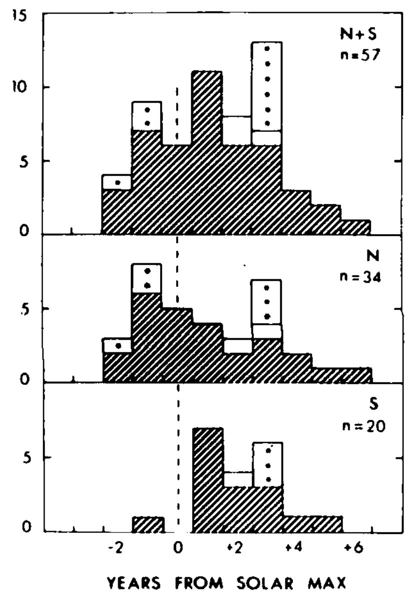

Figure 1. Histograms Showing Frequency of White-Light Flares vs Year From Solar Cycle Maximum, Plotted for Combined Northern and Southern Hemispheres (top), Northern Hemisphere (middle), and Southern Hemisphere (bottom). The total number of events in each panel is indicated. The shaded areas represent the (unbiased) distribution of WLF-producing active regions (only the first flare in the region is counted to produce the distribution). The mean of this distribution in the top panels is $+1.24$ yr ($\sigma/\sqrt{N} = 0.30$); the mean of the combined distribution of shaded and asterisked events is $+1.30$ yr ($\sigma/\sqrt{N} = 0.27$). Unshaded and unasterisked areas represent WLFs reported only by Sacramento Peak Observatory during the period June 1980-December 1982 (in which a concerted effort was made to detect WLFs). Because they would have biased the distribution, they are not included in the shaded areas. Events indicated by an area with an asterisk in it are WLFs that occurred in an active region where another WLF had already occurred during a single passage of the region across the solar disk

The total distribution of northern hemisphere WLFs (Figure 1) is, at first glance, suggestive of a bimodal cycle of activity. However, when we consider only the unbiased (shaded) distribution of northern WLF-producing regions it appears that the activity is better characterized by a rather abrupt commencement one or two years prior to solar maximum, with a slow decline thereafter. A similar rapid commencement and slow decline may also apply to the southern hemisphere, although in contrast to the northern hemisphere, the major portion of the southern activity

begins about one year after solar maximum. We note, however, one southern WLF (Event No. 4) that occurred one year before solar maximum.

Five active regions are known to have produced two or more WLFs, with one region (Hale 18405, June 1982) producing four in a three-day period. The time between successive WLFs in a given active region has ranged from less than 1 hour (04 June 1982) to 5 days (02-07 August 1972).

Figure 1 shows that the northern hemisphere has been 70 percent more productive in WLFs than the southern; this tendency, however, does not apply to cycle 21. Roy[74] also found a northern hemisphere dominance for WLFs, large non-WLFs, and complex active regions, while north-south asymmetries in non-complex regions and total hemispheric sunspot areas were much less noticeable.

With regard to the delay in the onset of the major portion of WLF activity in the southern hemisphere, it is interesting to note that the southern WLFs differ in another, independently observable way, namely, their latitude distribution (Figure 2). Here we see that the southern WLF-producing regions have a mean latitude of $13 \pm 2°$, compared with $18 \pm 1°$ for the north. Together, the temporal and heliographic differences suggested in Figures 1 and 2 are in agreement with earlier observations, for example, Kiepenheuer,[75] which indicated both a delay and an equatorward displacement in southern hemisphere sunspot activity in general. Thus, the WLF data, despite the small sample size, may reflect subtle asymmetries in the global activity characteristics of the sun.

The question of the existence of active longitudes on the sun has been discussed at length and remains controversial (see for example, Warwick,[76] Sakurai,[77] Wilcox and Schatten,[78] Haurwitz,[79] Svestka,[80] Vitinskij,[81] Dodson and Hedeman,[82] and Speich et al[83]). Observationally, the approach usually consists of plotting some index of activity as a function of heliographic longitude. Since the sun is a rotating fluid body, however, the assignment of a longitude to a particular point on the sun does not form a permanently reliable reference frame. Ordinarily, the Carrington rotation rate (13. 19890 deg/day) is assumed in defining the heliographic longitude. It can be argued, of course, that a failure to detect recurring activity at a particular longitude is merely a result of choosing the wrong solar rotation rate. Even small errors in the assumed rotation rate would, in time, accumulate large displacements in the longitudes of recurring features of activity if they existed. For this reason, various rates have been applied in the search for localites of persistent activity (for example, Wilcox and Schatten,[78] and Haurwitz[79]). The problem with WLFs is that, in order to obtain a sufficiently large sample of events, data over at least one solar

(Due to the large number of references cited above, they will not be listed here. See References, page 33.)

cycle (and preferably several cycles) should be used. Such long spans of time greatly increase the likelihood that any location of recurring WLF activity might become lost or confused.

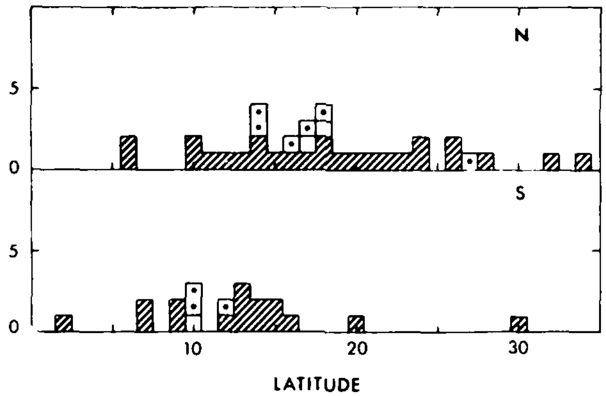

Figure 2. Distribution in Heliographic Latitude (degrees) of WLFs in Northern (top) and Southern (bottom) Hemispheres. Representation of shaded and asterisked events is identical to Figure 1. The means of the shaded (unbiased) distributions of WLF-producing active regions are 18.4 deg ($\sigma/\sqrt{N}$ = 1.4) in the northern hemisphere and 13.1 deg ($\sigma/\sqrt{N}$ = 1.6) in the southern

In this report we consider only the Carrington reference frame, and plot the longitudes of WLFs in solar cycles 19, 20, and 21 (Figure 3). Figure 3 displays the northern and southern hemispheres separately, using 30-degree longitude bins; the total for all three cycles is also plotted. Clearly, there is no evidence for preferred longitudes persisting from one cycle to another; neither is there persuasive evidence for any longitude of recurring activity within a single cycle, except possibly in the southern hemisphere during cycle 21. Here we find 10 of the 12 southern hemisphere WLFs occurring within a 60-degree span of longitude (these 10 flares, however, originated in only seven different active regions, where the total number of southern WLF-producing regions was nine). The (binomial) probability of randomly finding at least seven out of nine regions in only 1/6 the available longitude on the sun is 0.0001, which is unlikely enough to warrant suspicion for the existence of an active longitude. The seven regions in this zone appeared during June and July 1980 (two successive rotations), January and February 1981 (two successive rotations), and June and December 1982.

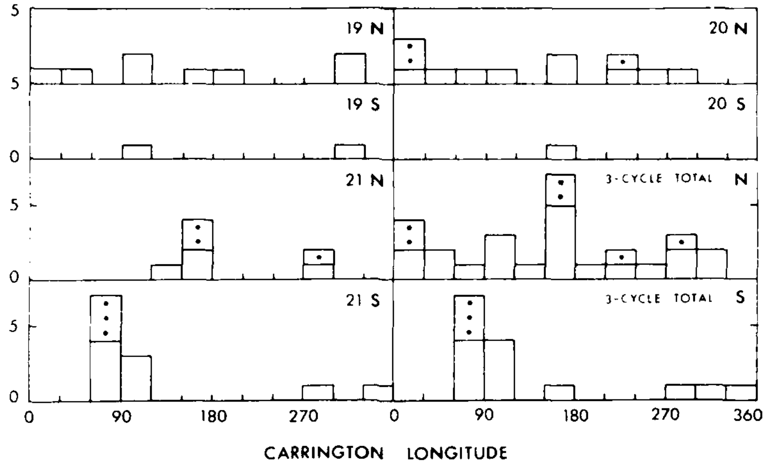

Figure 3. Distribution in Carrington Longitude of WLFs in Solar Cycles 19, 20, and 21, for Northern and Southern Hemispheres Separately. Events marked by an asterisk indicate WLFs occurring in an active region that had previously produced one or more WLFs during a single transit across the solar disk

In Figure 4 we plot the heliocentric angular distances of all WLFs with known coordinates, in 30° bins. We also plot the inverse of the solar limb darkening function at 5000 Å, normalized to the number of WLFs occurring in the 0°-30° bin. It might be expected, if WLFs were elevated structures located high in the solar atmosphere, that their discovery rates would increase toward the limb, owing to the increase in contrast offered by the darkening of the solar background. The sample size in Figure 4 is probably too small to draw any definite conclusion, although it does appear that WLF occurrences at 60-90 heliocentric degrees do not exceed the number occurring at 30-59 degrees. This is in contrast to an expected increase by a factor of two based on simple limb darkening. Without additional information it is possible only to speculate on this result. Certainly, foreshortening and radiative transfer effects within the flare could play a role; or, if WLFs were located sufficiently deep in the atmosphere, a significant amount of photospheric absorption would be expected at large heliocentric distances.

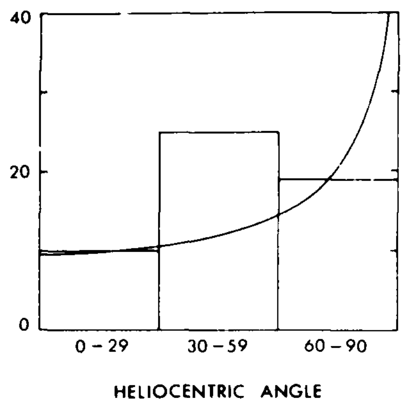

Figure 4. Distribution of WLFs in Heliocentric Angular Distance (degrees). The plotted curve is the inverse of the solar limb-darkening function at 5000 Å, normalized to the number of events in the 0-30° bin

4.3 Association of WLFs With Other Flare Emissions

4.3.1 Hα, 1-8 Å X-RAYS, AND MICROWAVES

In Figures 5, 6, and 7 we present histograms of the Hα flare class, soft X-ray class, and peak ≧ 8 GHz emission, respectively, for all WLFs in Table 1 for which these data were available. From each of these histograms it is evident that continuous emission in the optical range is a phenomenon associated with "big flares," as measured at any wavelength. To date, no definite case of a WLF has been associated with an Hα subflare; and, with only a few exceptions, the associated Hα flares have been classified as bright (B). Only one WLF was associated with a soft X-ray event smaller than M5 (M4.6 for the WLF on 27 January 1981). We note that three of the four microwave bursts in Table 1 with S_p(≧ 8 GHz) < 100 sfu (1 sfu = 10^{-22} W m^{-2} Hz^{-1}) occurred in 1958, when the worldwide solar radio patrol lacked much of the overlapping coverage that is available today. The ~9 GHz burst associated with the 27 September 1969 WLF had a flux density peak of only 10 sfu at the time of the continuum emission with S_p(2 GHz) = 107 sfu; Sp(~9 GHz) for the entire event was ~64 sfu at ~0435 UT. *Until other WLFs with similar radio spectra* are observed, the latter event must remain suspect [possibly a type (2) event; see Section 3]. [We note, from Table 2, that the sunspot area of the active region in which this flare occurred (McMath 10333) was anomalously small (≲ 100 millionths) in comparison to other WLF active regions.] The next smallest ≧ 8 GHz burst associated with a WLF was the 120 sfu burst at ~1530 UT on 05 June 1982. From the three histograms it can be seen that the "typical" (median) WLF is associated with a 2B Hα flare, an ~X3 soft X-ray event, and a ≧ 8 GHz burst with peak flux density ~4000 sfu.

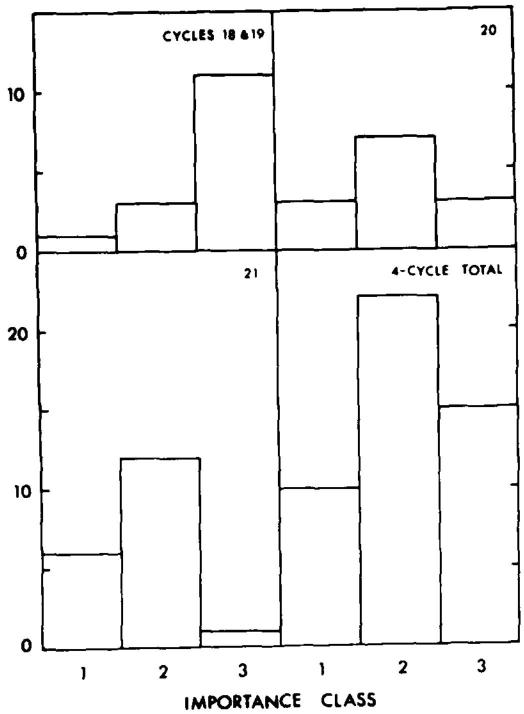

Figure 5. Hα Importance Classes for WLFs in Solar Cycles 18 and 19, 20, and 21

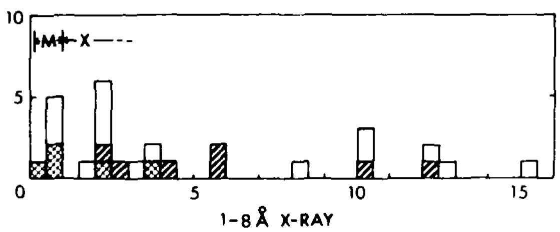

Figure 6. Peak 1-8 Å X-ray Flux at 1 AU (10^{-1} erg s^{-1} cm^{-2}) for WLFs Where Soft X-ray Data are Available. Bin size is 0.05 erg s^{-1} cm^{-2}. The flux range corresponding to class M, and the lower limit of class X, are indicated. Hatched and double-hatched areas represent WLFs observed at Sacramento Peak Observatory during the period June 1980 - December 1982; double-hatched area indicates the subset of Sacramento Peak events visible only below 4000 Å

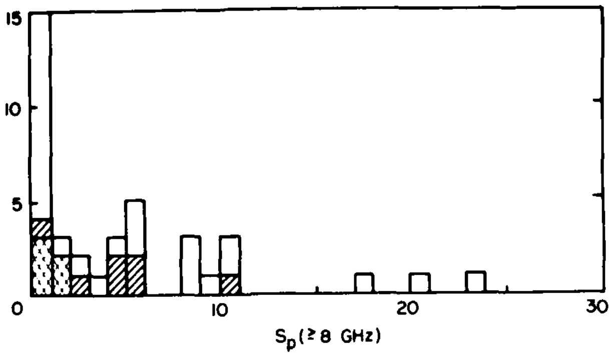

Figure 7. Peak Microwave Burst Flux at any Frequency ≧ 8 GHz for WLFs Where Data are Available (flux in 10^3 sfu, where 1 sfu = 10^{-22} W m^{-2} Hz^{-1}). Hatched and double-hatched areas are as described in Figure 6. Peak flux densities used for Event Nos. 35 and 44 were 8101 and 2700 sfu, respectively. One event (No. 28), in which the peak flux was reported to be 180,000 sfu, is not included here

Notwithstanding the apparent association of WLFs with "big flares", in Figure 5 we can see a trend toward the detection of WLFs associated with increasingly smaller Hα flares, as patrol observations have become both more systematic and sophisticated. A similar decline in the average size of the flash phase emissions associated with WLFs is illustrated in Figures 6 and 7, where we have indicated those events observed at Sacramento Peak Observatory since June 1980 when the Multiple Band Polarimeter patrol was established. We have further identified the subset of Sacramento Peak Observatory events that were observed only below 4000 Å by the Multiple Band Polarimeter (Event Nos. 45, 49, 51, 52, and 54 in Table 1; although continuum was marginally detectable at $\lambda \gtrsim 4000$ Å for Event Nos. 49 and 52, it would probably not have been noted had it not been for its observation at shorter wavelengths). The median S_p (≧ 8 GHz) value for all events in Figure 7 is 2700 sfu. If we ignore the three events in the lowest energy bin (S_p < 100 sfu) that occurred in 1958 when the worldwide radio patrol of the sun was in its infancy, the median becomes 3813 sfu. In comparison, the median peak flux density for the Sacramento Peak Observatory events is 2050 sfu, nearly a factor of two smaller. As is evident from Figure 7, it is primarily the events detectable only below 4000 Å that are responsible for the lower Sacramento Peak Observatory median value (compare with the results of Neidig and Cliver[84]). In fact, if we omit these events,

84. Neidig, D.F., and Cliver, E.W. (1983) The occurrence frequency of white-light flares, Solar Phys. 88:275.

the median value of the Sacramento Peak Observatory events is also 4000 sfu. We note that the WLFs observed only below 4000 Å by the Multiple Band Polarimeter also tend to have smaller associated Hα flares and weaker soft X-ray bursts.

It is interesting to note that the maxima of the microwave peak flux density spectra of the five WLFs observed only below 4000 Å occurred at frequencies ≳ 9 GHz, consistent with that observed for the bulk of the other events in Table 1 (Figure 8). This is significant, since it indicates that relatively strong and, hence, low-lying magnetic fields characterize the burst emission source.[85] We point out that three of the events with spectral maximum < 9 GHz occurred in 1958.

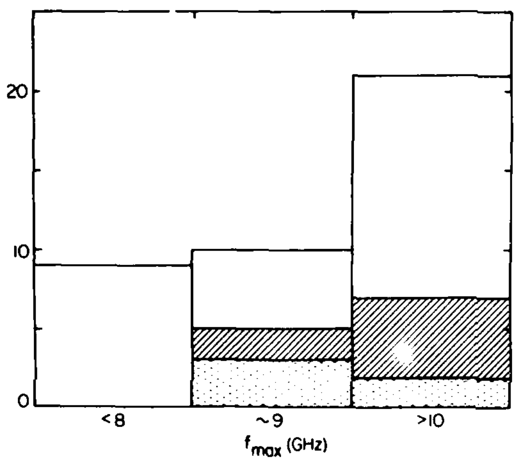

Figure 8. Distribution of the Microwave Burst Spectral Maximum, f_{max}, for WLFs Where the Microwave Spectrum is Known. Only one maximum is plotted for each WLF; for Event Nos. 34 and 35 the 5 GHz maximum was used. Event Nos. 21, 23, 24, 25, and 27 were included in the ">10" bin. Hatched and double-hatched areas are as described in Figure 6

4.3.2 PROTON EMISSION AND TYPE II/IV BURSTS

McCracken[86] and Svestka[12] called attention to a high degree of association between continuous emission in flares and solar proton events. Prior to satellite observations, these proton events were detected by neutron monitors (Ground Level Events, since 1942) or riometers (Polar Cap Absorption Events, since 1955). For the WLF events in Table 1 that occurred after 1955, the association with >10 MeV proton events ranges from at least 52 percent (22/42) to as high as 81 percent (34/42) if one assumes that protons were produced in all WLFs for which the association is questionable (masked proton events or ambiguous flare associations; see

85. Guidice, D.A., and Castelli, J.P. (1975) Spectral distribution of microwave bursts, Solar Phys. 44:155.

86. McCracken, K.G. (1959) A correlation between the emission of white light and cosmic radiation by a solar flare, Nuovo Cimento 13:1081.

Explanation of Table 1). If we consider only western hemisphere events in an attempt to remove propagation effects, the percent association improves somewhat, to a range of 74 percent (14/19) to 84 percent (16/19).

Svestka[87,88] accounted for the observed high degree of association between WLFs and proton events by proposing a single acceleration process for energetic flare particles, in which some of the impulsive phase protons bombarded the lower chromosphere and upper photosphere to produce the white-light emission, while others escaped into the interplanetary medium to produce the proton event. Other lines of evidence, however, do not favor a direct connection between continuous emission in flares and proton events. First of all, the reverse association connecting every proton event to a WLF has not been demonstrated. In fact, Cliver et al[89] have recently reported a class of relatively large proton events associated with flares that do not have prominent flash phase emissions and that can originate in relatively simple magnetic configurations. This type of event is in marked contrast to the flares in Table 1, which generally show strong flash phase emissions and complex magnetic fields. Moreover, current ideas on flare acceleration of the protons detected at Earth emphasize second-stage, that is, shock-related processes (Svestka and Fritzova-Svestkova,[90] and Kahler et al[91]) over flash phase acceleration processes to which the white-light emission appears to be more closely related (Svestka and Simon,[64] p. 86). Thus, we suspect that the observed association is an example of the "Big Flare Syndrome"[92] which states, in effect, that big flares tend to be outstanding in all wavelengths and energy ranges, and cautions about overinterpreting correlations observed in samples of big flares.

If the association between WLFs and proton emission is in fact due to the Big Flare Syndrome, then one might expect the degree of association to degrade as continuum emission is detected in smaller flares. Unfortunately, the five "smaller" WLFs that were observed only below 4000 Å at Sacramento Peak Observatory were all either eastern hemisphere flares and/or occurred when a proton event was already in progress. We do note, however, that none of these five events was associated with a reported Type II burst, generally regarded as a characteristic of proton flares (Lin,[93] and Svestka and Fritzova-Svestkova[90]).

Overall, the association between WLFs and Type II bursts is 59 percent (22/37). For the reverse association, Type IIs occur much more frequently ($\gtrsim$ 60/yr during the solar maximum, after Maxwell and Thompson,[94] and Dodge[95]) than WLFs (~ 15/yr during solar maximum[84]). WLFs also show a strong association with Type IV bursts (71 percent; 27/38) and Type III bursts (79 percent; 30/38).

(Due to the large number of references cited above, they will not be listed here. See References, page 33.)

5. CONCLUSIONS

From this study of WLFs, the active regions in which they occur, and their association with other flare emissions, we draw the following conclusions:

(1) The active regions that produce WLFs tend to have large sunspot group areas ($\gtrsim$ 500 millionths), with complex delta magnetic structures in which opposite magnetic poles are located in close proximity to one another (typically EKC in the Solar Geophysical Data classification scheme).

(2) In regard to the time of their occurrence within the solar cycle:

   (a) Northern hemisphere WLF activity is characterized by a rather abrupt commencement one or two years prior to solar maximum, with a slow decline thereafter;

   (b) Southern hemisphere WLF activity follows the same pattern, but, with the exception of one event, begins approximately one year after solar maximum.

   (c) The combined WLF activity in both hemispheres peaks approximately one year after solar maximum.

(3) In regard to their location on the sun:

   (a) WLFs exhibit a north-south asymmetry with 70 percent more events having been observed in the northern hemisphere; during the 21st solar cycle, however, southern hemisphere events have dominated (12 of 19 cases);

   (b) WLFs in the southern hemisphere have a mean latitude of 13 $\pm$ 2°, compared with 18 $\pm$ 1° for the northern hemisphere WLFs (compare with conclusion (2) above);

   (c) WLFs do not show evidence for favoring certain preferred longitudes, even within a given solar cycle (a possible exception is the southern hemisphere in the 21st solar cycle, where seven of the nine active regions that produced WLFs occurred within a 60° span of longitude).

(4) White light emission in solar flares is characteristically accompanied by intense Hα, soft X-ray, and microwave emission. The smallest (high confidence) Hα class, soft X-ray class, and $\geqq$ 8 GHz peak radio emission of WLFs observed to date are 1B (several cases),* M4.6 (27 January 1981), and 120 sfu (05 June 1982). Median values for these associated parameters are 2B, ~X3, and ~4000 sfu.

(5) WLFs exhibit a high degree of association with solar proton events ($\geqq$ 75 percent for western hemisphere WLFs), Type II bursts (~60 percent), and Type IV bursts (~70 percent). We argue, however, that their strong association with interplanetary proton events may be a consequence of the Big Flare Syndrome rather than evidence for a close physical link between the two phenomena.

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*The 06 July 1968 WLF (1N) was located nearly at the limb, making its classification doubtful.

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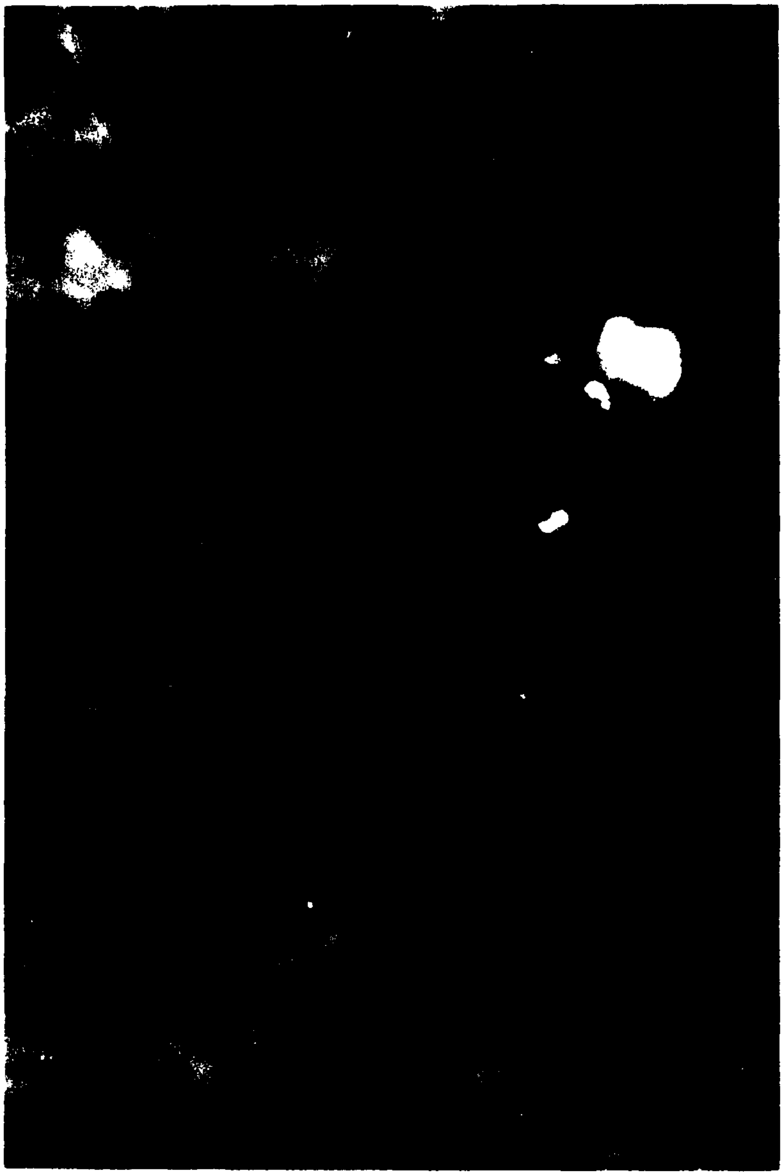
Appendix A

Morphology, Spectra, and Energetics of WLFs

The scope of this report does not encompass physical interpretations of White Light Flares (WLFs). Therefore, detailed descriptions of WLF morphology, spectra and energetics are not included in the main body of the discussions. For the sake of completeness, however, the known salient features of WLFs will be briefly summarized in this appendix to offer the reader some perspective on the observations relating to the physical processes occurring in these flares.

WLFs appear as small bright patches, arches, or ribbons of emission, usually located within the penumbras of large, complex sunspot groups (see Figure A1 and references cited in catalog). Occasionally the emission may appear diffuse; or it may assume the form of a moving wave-like transient. In general, it can probably be stated that WLFs have the same diversity of structure that is known to occur in Hα flares, although the WLFs are much smaller than their Hα counterparts. The total area of WLF emission averages 6×10^{17} cm^2 (Table A1), with a duration ordinarily less than 10 min; this represents only a few percent of the flare's total area in Hα, and only 10-20 percent of the Hα flare duration. Nevertheless, WLF emissions are so intense that within their small areas and durations they may radiate as much energy as the entire Hα event ($\sim 10^{30}$ erg). Their peak power output approaches 10^{28} erg/sec (Table A1).

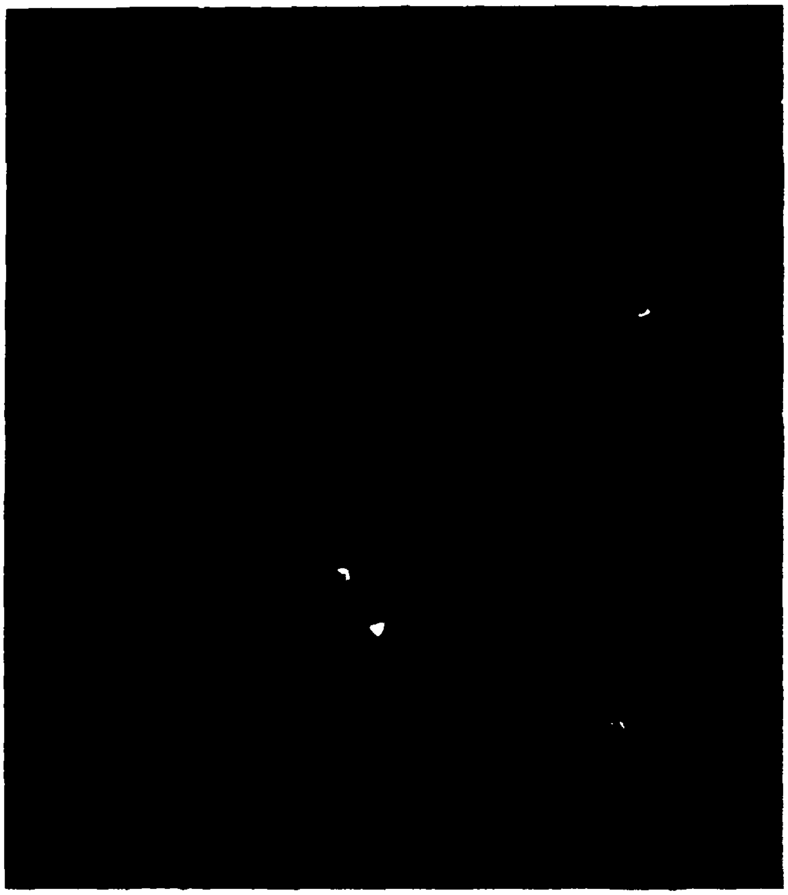


(a)

Figure A1. Photographs of Several White-Light Flares, Illustrating Their Enhanced Emission at Short Wavelengths and Their Various Structural Forms; North is at the Top, East to the Left, in All Frames. (a) 24 April 1981, 1357 UT, photographed at 3610 Å. Note strands of emission in the large, bright patch, as well as two small kernels (lower) connected by a loop-like feature. The N-S dimension of the sunspot group is 133 arcsec

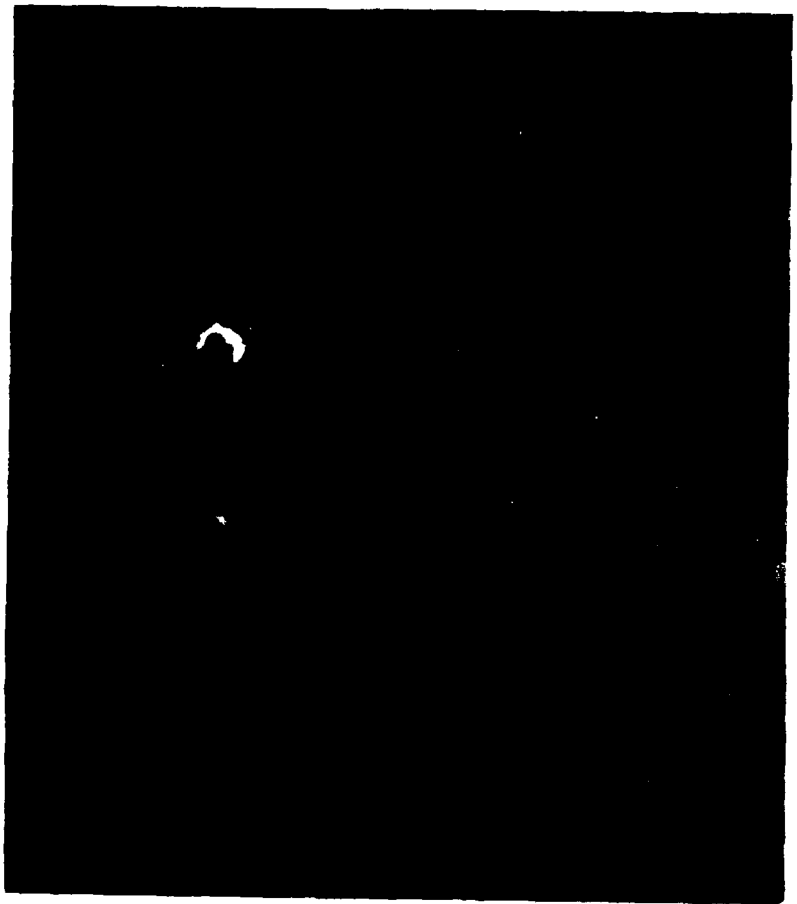
(b)

Figure A1. Photographs of Several White-Light Flares, Illustrating Their Enhanced Emission at Short Wavelengths and Their Various Structural Forms; North is at the Top, East to the Left, in All Frames. (b) 24 April 1981, 1357 UT, photographed at 4275 Å. Note the decrease in the flare contrast at this wavelength, compared with 3610 Å



(c)

Figure A1. Photographs of Several White-Light Flares, Illustrating Their Enhanced Emission at Short Wavelengths and Their Various Structural Forms; North is at the Top, East to the Left, in All Frames. (c) 04 June 1982, 1332 UT, 3610 Å. Note several small kernels; the N-S dimension of the sunspot group is 117 arcsec



(d)

Figure A1. Photographs of Several White-Light Flares, Illustrating Their Enhanced Emission at Short Wavelengths and Their Various Structural Forms; North is at the Top, East to the Left, in ' Frames. (d) 04 June 1982, 1421 UT, 3610 Å. Note white-light flare ribbons

Table A1. White-Light Flare Energetics. (Most energy estimates assume emission in a wavelength band that does not greatly exceed the visible range)

Event No. (from Table 1)	Date	F[a]	A[b]	$\int F\,dA$[c]	E[d]	Reference
26.	1967 May 23	7×10^{9}	8×10^{17}	3×10^{27}	6×10^{29}	39,40
31.	1970 Nov 17	5×10^{10}	2×10^{17}	1×10^{28}	6×10^{30}	14
34.	1972 Aug 7	1.5×10^{10}	6×10^{17}	6×10^{27}	6×10^{29}	45,46,47
42.	1980 Jul 1	1.6×10^{10}	1.4×10^{18}	4.5×10^{27}	1.2×10^{30}	55
45.	1981 Apr 24	3.6×10^{10}	3.4×10^{17}	7.0×10^{27}*	2.0×10^{30}*	57
20., 21., 24., 30.	Means for four WLFs	4×10^{9}	5.8×10^{17}	2×10^{27}	1×10^{30}	14
	Means for all nine WLFs	1.5×10^{10}	6.3×10^{17}	4.3×10^{27}	1.6×10^{30}	
	Hα emission in typical 2B/3B flare	5×10^{7}	2×10^{19}	1×10^{27}	1×10^{30}	14

[a] Peak flux in flare (erg sec^{-1} cm^{-2})

[b] Maximum area (cm^2)

[c] Peak Power (erg/sec)

[d] Total energy (erg)

* These values are revised from those cited in Reference No. 57 (see Reference A4).

The occurrence of a WLF over the dark background of a penumbra improves the contrast of the flare emission. Yet the brightest WLF patches ever seen have occurred just outside the penumbra, against the undisturbed solar photosphere. In terms of wavelength-integrated intensity the WLF, in some cases, exceeds the surface brightness of the surrounding photosphere by more than 50 percent.

In three of the WLFs observed with the Multiple-Band Polarimeter (MBP) the data were recorded through the polarization analyzer in five wavelengths (Event Nos. 44, 46, and 47). No detectable level of polarization was found at any wavelength in any of these flares, that is, linearly polarized emission, if present at all, was less than approximately 3 percent of the solar background intensity.

The optical spectra of WLFs show, in addition to continuum, many bright emission lines, including narrow ($\lesssim$ 0.1 Å) lines of neutral and singly ionized metals, broad lines of neutral and ionized helium, and the usual hydrogen Balmer line series. The latter are extremely broad, with full widths in Hα (width measured at the 5 percent enhancement level) exceeding 30 Å in some cases. Apparently, large Balmer line widths are a characteristic of WLFs in general (Slonim and Korobova,[14] Neidig[A1]); Neidig[A1] suggested that an Hα full width $\gtrsim$ 20 Å could be taken as a spectral line criterion for continuum emission in flares. The extreme broadening of the Balmer series in many WLFs results in a merging of the lines near H15 or H16 (as in Event Nos. 47, 50, 51, 53, 55 and 57). Thus, in these particular cases, the "Balmer limit" (3646 Å in the zero density limit) is advanced at least to approximately 3700 Å.

The Balmer continuum has now been positively identified in several WLFs discussed in the literature (Nos. 38, 47 and 48), although at least two cases are known (Nos. 32 and 36) in which a short-wavelength continuum was present without a measurable Balmer jump. In all cases where Balmer continuum has been identified, a continuum extending toward longer wavelengths has also been seen. Hiei[50] (Event No. 38) and Neidig[57] (Event No. 47) attributed the latter continuum to emission by the negative hydrogen ion. This interpretation for Event No. 47, however, is now placed in serious doubt by the detection of a Paschen jump at ~8500 Å in the spectrum of the same flare.[A2]

A1. Neidig, D.F. (1978) Hα, Hard-X-ray, and microwave emissions in the impulsive phase of solar flares, Solar Phys. 57:385.

A2. Neidig, D.F., and Wiborg, P.H. (1983) Hydrogen recombination spectra in white-light flares, (submitted to Solar Physics).

Present estimates for the electron densities in the Balmer-emitting layers of flares assume that the Stark effect is the dominant broadening mechanism for the hydrogen lines (for example, Svestka[3]). If correct, electron densities $\sim 5 \times 10^{13}$ cm^{-3} are implied for flares in which the Balmer lines merge near H16.

Generally, the optical continua of flares are brightest at short wavelengths, especially below 4000 Å (compare photographs in Figure A1). This phenomenon may be related to the bluish color noted in a number of visual observations of WLFs (see references to Table 1, or Neidig[57]) although the cause for it is not completely understood. An increase in the flare contrast could be expected simply as a result of the decline in intensity of the solar background spectrum at short wavelengths. On the other hand, intense brightenings (~100 percent) have been observed in filtergrams at 3835 or 3862 Å when the corresponding emission at longer wavelengths was weak or absent (Event Nos. 39, 40, 41, and 44). The latter observations indicate differences in contrast too large to be attributed entirely to differences in the intensity of the solar background. Multiple Band Polarimeter observations of Event No. 47 indicated enhancements exceeding 300 percent at 3610 Å, with only 65 percent enhancement at 4275 Å. In this case, however, the contrast difference may not be so difficult to understand because the 3610 Å measurement includes a contribution from the Balmer continuum. The resolution of the problem of anomalous brightness below 4000 Å (but above the Balmer limit) awaits the analysis of spectrograms showing large intensity enhancements in this wavelength range; to date, no spectrographic data showing enhancements several times the photospheric background have been obtained.

White-light emission in flares is usually confined to a short period of time near the flare maximum as measured in other wavelengths. Only in a few cases have detailed comparisons been achieved between total white-light power and other emissions [Rust and Hegwer[47] (Event No. 36), Ryan et al[A3] (No. 44), and Kane et al[A4] (No. 47)]. In Event Nos. 36 and 47 the white-light power tracked the hard X-ray and microwave emissions in considerable detail, suggesting that high energy electrons might be the WLF energy source. On the other hand, the same types of correlations were rather poor for Event No. 44. Zirin[15] believes that the white-light event is associated with the thermal phase of the flare, although the appearance of white-light kernels prior to thermally-produced soft X-rays in several flares makes this idea difficult to accept in general.

A3. Ryan, J.M., Chupp, E.L., Forrest, D.J., Matz, S.M., Reiger, E., Reppin, C., Kanbach, G., and Share, G. (1983) Gamma-ray observational constraints on the optical continuum emission from the white-light flare of 1980 July 1, Astrophys. J. **272**:L61.

A4. Kane, S.R., Love, J., Neidig, D.F., and Cliver, E.W. (1983) Characteristics of the white-light source in the 24 April 1981 solar flare, Astrophys. J. Letters (manuscript in preparation).

Although the interpretation of the observations discussed herein is far from complete, it is commonly believed that the WLF phenomenon originates from heating the relatively deep layers of the solar atmosphere, presumably the low chromosphere or upper photosphere. Presently accepted flare models, on the other hand, place the actual energy release much higher—in the low corona—with subsequent transport of energy to the lower atmosphere by heat conduction or high energy particles. The efficiency of these transport processes decreases rapidly with depth in the atmosphere; yet the radiative losses in WLFs are enormous (Table A1). Peak fluxes of approximately 3×10^{10} erg sec^{-1} cm^{-2} are observed in the brighter events; this is ~ 100 times greater than the Hα line emission at the same location in the flare (Slonim and Korobova,[14] Neidig[57]). If the thickness of the emitting layer is assumed to be 100 km, then the energy deposition rate must exceed 10^3 erg sec^{-1} cm^{-3}. The problem of how to transport such a large amount of energy from the corona to the deep atmosphere remains a fundamental question in flare physics.

Appendix B

White-Light Flares Referenced in the Literature but Not Included in Table 1

Table B1. White-Light Flares Referenced in the Literature but not Included in Table 1

No.	Date	Reference	Reason for Exclusion
1	07 Dec 1938	Richardson and Minkowski;[6] Svestka[12]	Type (2) event (see Section 3)
2	11 Aug 1954	Miller[16]	Lack of associated phenomena; short duration
3.	27 Aug 1956	Severny;[7] Svestka[12]	Type (2) event (see Section 3)
4.	30 Aug 1957	McNarry[17]	Lack of associated phenomena
5.	07 Sep 1957	Kiepenheuer and Kuenzer[5]	Limb or Type (1) event (see Section 3)
6.	07 Mar 1959	Dunn et al;[B1] Jefferies and Orrall[B2]	Limb event
7.	09 Jun 1959	Dunn et al,[B1] Jefferies and Orall[4]	Limb event
8.	14 Jul 1959	Kvicala et al[B3]	Reference is only a listing similar to Quarterly Bulletin of Solar Activity
9.	23 May 1967 (1937 UT)	McIntosh and Donnelly[13]	At the limit of detection
10.	16 Jul 1970	Zhang and Smartt[B4]	Limb event
11	04 Jul 1974 (1843 UT)	Feibelman[48]	At the limit of detection
12	05 Sep 1981	Wang and Chen[B5]	Exceptionally small associated Hα and X-ray flare. (Type (2) event? See Section 3)

Note: Michard[B6] discusses a number of flares which show continuum on spectrograms; these events, however, were not listed according to dates and times.

B1. Dunn, R. B., Jefferies, J. T., and Orrall, F.Q. (1960) The line and continuous emission observed in two limb flares, Observatory 80:31.

B2. Jefferies, J. T., and Orrall, F.Q. (1961) On the interpretation of prominence spectra. II. The line and continuous spectrum of the spray-type limb event of March 7, 1959, Astrophys. J. 133:946.

B3. Kvicala, J., Hrebik, F., Olmr, J., Svestka, Z., and Drivsky, L. (1961) Observations of flares at the Ondrejov Observatory in the year 1959, Bull. Astron. Inst. Czech. 12:47.

B4. Zhang, Z., and Smartt, R. N. (1983) Electric field measurements in solar flares, Solar Phys. (submitted).

B5. Wang, Z., and Chen, X. (1981) Spectrum of the white-light solar flare of September 5, 1981, Chinese Astrononical Society, Astronomical Circular No. 11, p. 1.

B6. Michard, R. (1959) Spectroscopie des eruptions solaires dans le programme Francais de l' A.G.I., Ann. Astrophys. 22:887.

Appendix C

White-Light Flares Whose Only Reference is QBSA (1934-1976) or SGD (Aug 1964-1979)

Table C1. White-Light Flares Whose Only Reference is the Quarterly Bulletin of Solar Activity (1934-1976) or Solar Geophysical Data (Aug 1964-1979)

Event No.	Year	Month	Day	Hα Start	Hα Max.	Hα End	Hα Class	Lat.	Long.	Obs.
1.	1956	Aug	31	?	1245	?	3	N15	E15	Grnwch
2.	1957	Sep	03	1210	1215	1222	1	S17	W09	Uccle
3.	1957	Sep	19	0744	0802	0815	2	N24	E03	Crim
4.	1957	Oct	14	0904	1040	1130	1	S24	E58	Uccle
5.	1958	Feb	28	0800	0804	0825	2	S13	W34	Crim
6.	1958	June	23	0713	0715	0837	3	N30	E50	Bakou
7.	1958	July	12	0802	0816	0843	2	S23	W73	Schauin
8.	1958	Dec	10	0219	0220	0254	2	N02	E20	Voro
9.	1958	Dec	12	0210	0226	0244	1+	S03	W02	Voro
10.	1959	Jan	22	1109	1125	1138	2	N10	W03	Kiev, Ky
11.	1959	Apr	08	0903	0917	0947	2	N25	E80	Capri F
12.	1959	Nov	16	0933	?	1020	1	N03	E05	Capri F
13.	1960	May	13	0522	?	0733	3+	N30	W64	Ond
14.	1960	Aug	26	0847	0852	0905	3	N16	W90	Bakou
15.	1961	July	12	1003	1031	1206	3+	S07	E25	Ond
16.	1962	July	14	0655	0708	0820	2	N02	E75	Bakou

Table C1. White-Light Flares Whose Only Reference is the Quarterly Bulletin of Solar Activity (1934-1976) or Solar Geophysical Data (Aug 1964-1979) (Contd)

Event No.	Year	Month	Day	Hα Start	Hα Max.	Hα End	Hα Class	Lat.	Long.	Obs.
17.	1966	June	11	1036	?	1112	2N	N20	E27	Mont
18.	1966	July	11	0900	?	1030	3N	N35	W90	Capri S
19.	1966	Sep	02	0542	0600	0800	3B	N24	W56	Abst
20.	1968	Oct	29	1222	1223	1300	2B	S16	W12	San M
					1234					
21.	1969	Apr	18	0436	0440	0506	1B	N23	E33	Koda
22.	1969	Apr	18	1655E	1701	1757	-F	N07	W27	San M
23.	1969	Apr	19	0858	0912	0935	1N	N21	00	Koda
24.	1969	Nov	23	0958	1004	1125	1B	N15	W19	Uccle
					1019					
25.	1970	Jan	04	2127	2130	2207	1N	S17	W76	Boul
					2137					
26.	1972	Apr	01	0650	0653	0659	-F	S16	W42	Ath
27.	1972	Apr	05	0503	0506	0510	-N	S10	W19	Tehr
28.	1972	Apr	05	1128E	1130	1134	-N	S10	W23	Tehr
29.	1972	Apr	18	1503	1507	1526	SN	S12	E38	Pale
30.	1972	Apr	21	0807	0810	0813	-F	S11	W03	Tehr
31.	1972	Apr	21	0844	0846	0855	-N	S12	E02	Tehr
32.	1972	Apr	21	2249E	2250	2305	-F	S11	W05	Pale

Table C1. White-Light Flares Whose Only Reference is the Quarterly Bulletin of Solar Activity (1934-1976) or Solar Geophysical Data (Aug 1964-1979) (Contd)

Event No.	Year	Month	Day	Hα Start	Hα Max.	Hα End	Hα Class	Lat.	Long.	Obs.
33.	1972	May	04	1644E	1644	1650	-F	S15	E52	Ramy
34.	1972	May	05	0638E	0641	0647	-N	N08	E33	Tehr
35.	1972	May	05	0824	0826	0832	-F	S16	E49	Tehr
36.	1972	May	05	1722	1725	1742	-F	S13	E43	Ramy
37.	1972	May	12	1907E	1909	1913	-N	N20	W48	Pale
38.	1972	May	16	0112	0116	0132	-N	S04	E30	Pale
39.	1972	May	16	0217	0224	0240	SN	S05	E29	Pale
40.	1972	May	16	0307	0319	0346	1B	S05	W15	Pale
41.	1972	May	18	1457E	1457	1520	-N	S16	E26	Ath
42.	1972	May	26	1625E	1628	1640	-F	N11	E54	Ramy
43.	1979	Oct	11	1152E	1202	1217D	-F	N10	E63	Khar

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